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## ON THE INHERITANCE OF ACQUIRED MODIFICATIONS OF BEHAVIOR

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It has always been difficult for students of psychology to convince themselves that *some* modifications of behavior in the individual might not be inherited. This feeling that innate forms of action may require for their explanation the assumption that some of them, at least, originated through the life experiences of individuals, has been widespread, as a few typical quotations will serve to show.

"We must suppose that the physical changes which the nervous elements undergo can be transmitted from father to son. . . . The assumption of the inheritance of acquired dispositions or tendencies is inevitable, if there is to be any continuity of evolution at all. We may be in doubt as to the extent of this inheritance; we cannot question the fact itself." (Wundt, *Human and Animal Psychology*, Eng. tr. by Creighton and Titchener, p. 405.)

"I believe, with Wundt, that 'die zweckmässigen Reflexbewegungen stabil und mechanisch gewordene Willenshandlungen sind;' I believe, with Ward, that 'volition or something analagous to it' has, in the race as in the individual, invariably 'preceded habit;' and I believe, with Cope, that even 'the automatic involuntary movements of the heart, intestines, reproductive systems, etc., were organized in successive states of consciousness.'" (Titchener, *The Psychology of Feeling and Attention*, pp. 299-300.)

"Every element has shaped and tempered it [the soul]. Its long experience with light and darkness, day and night, has fashioned its rhythm indelibly. Heat and cold, the flickering of flame, smoke and ashes, especially since man learned the control of fire, have oriented it toward both thermal extremes. Cloud forms have almost created the imagination. Water and a long apprenticeship to aquatics and arboreal life have left as plain and indelible marks upon the soul as upon the body. Sky, wind, stars, storms, fetichism, flowers, animals, ancient battles, industries, occupations, and worship have polarized the soul to fear and affection, and created anger and pity." (Hall, *Adolescence*, Vol. 2, p. 69.)

"Although, as yet, the evidence in favor of the inheritance of acquired characters is inconclusive, it is of sufficient importance to make it impossible to disregard entirely the possibility that such inheritance has played a large rôle in adaptive evolution." (Watson, *Behavior*, p. 179.)

The most outspoken opponent of such views is Thorndike: "The burden of evidence is thus against the transmission of acquired mental traits. The strengthening of a connection between a situation and a response by an individual seems unlikely to modify his germs so as to reproduce, in the children developing therefrom, a stronger bond between that situation and that response than they would otherwise have possessed. Similarly for the transmission of an abolition or weakening of a connection." (*The Original Nature of Man*, pp. 234-235.)

It must be admitted that many advocates of the Lamarckian hypothesis in psychology have stated their positions in terms which have tended to prejudice many minds against the whole theory. They have, that is, assumed that originally the acts which were transmitted were acquired by the organism in a deliberate, or voluntary, or purposeful fashion, by methods similar to those involved in the more complicated sorts of learning in man, that they then, in the individual, became mechanised as habits, and so were transmitted. As an extreme form of such doctrines, we have the view that instinct is "lapsed intelligence;" in its more moderate expressions, the view that reflexes, for example, are degenerate forms of acts that were once "voluntary" and attended by a high degree of consciousness. Even so careful a writer as Titchener allows himself the use of analogies which leave the impression on the mind of the reader that he is arguing for a mild form of the lapsed intelligence theory. The unconscious movements of man today, he says, are the descendants of past conscious movements. He goes on to argue his case.

"There is, first of all, the argument from the analogy of the individual lifetime. We learn to swim, to bicycle, to typewrite, to play a musical instrument, with conscious intent and with a constant accompaniment of consciousness; later on, if we practise enough, we do these things unconsciously. If however, what are called 'voluntary actions' may degenerate into 'secondary reflexes' in the course of a few weeks or months or years, it is at least possible that the ingrained physiological reflexes may have a conscious ancestry in the history of the race."<sup>1</sup>

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<sup>1</sup> Titchener, E. B. *A Textbook of Psychology*. p. 452.

It is possible that Titchener does not mean to press his analogy so far; but there are others enough who do. Darwin writes: "It seems probable that some actions which were at first performed consciously, have become through habit and association converted into reflex actions, and are now so firmly fixed and inherited, that they are performed, even when not of the least use. . . . It is scarcely credible that the movements of a headless frog, when it wipes off a drop of acid or other object from its thigh, and which movements are so well co-ordinated for a special purpose, were not at first performed voluntarily, being afterwards rendered easy though long-continued habit so as at last to be performed unconsciously, or independently of the cerebral hemispheres."<sup>2</sup>

It is natural enough that, as knowledge of the characteristic methods of animal learning increased, attempted explanations of the inheritance of acquired forms of behavior which appealed to any sort of deliberation or choice or "conscious intent" on the part of the organisms who first acquired those acts should have fallen into discredit, and the whole theory with them.

But that it is not necessary to hold to any form of the lapsed intelligence theory, to believe that innate forms of behavior were originally voluntary, or that they were attended in their development by any sort of consciousness at all, was demonstrated in principle by Herbert Spencer more than half a century ago. Consider, he says, the case of a simple aquatic creature with rudimentary eyes. Such a creature can be affected by opaque bodies moving in the water only when they are close at hand. But just because they are near by when glimpsed, the chances are high that they will soon afterward come into contact with the organism. In such cases, sight is "little more than anticipatory touch," the visual impression is habitually followed by a tactual one. Now tactual impressions are typically followed by contractions, so that "there constantly occurs the succession—a visual impression, a tactual impression, a contraction." What will then happen is that "the several nervous states produced will become so consolidated that the first cannot be caused without the others following—the visual impression will be instantly succeeded by a nervous excitation like that which the tactual impression produces, and this will be instantly succeeded by a contraction. There will then occur a contraction in anticipation of touch." The sequence, originally sight-touch-contraction, be-

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<sup>2</sup> The Expression of the Emotions in Man and Animals. pp. 39-40.

comes sight-contraction. The process may then go on producing still more complicated mechanisms, and the effects of such individual modifications Spencer supposes to be inherited. Thus complicated innate forms of behavior arise, not by a lapse from conscious and deliberate forms, but by the compounding of simpler elements in a fashion which is essentially automatic.<sup>3</sup>

Spencer, to be sure, was dealing with hypothetical processes in hypothetical organisms. Actual evidence of the occurrence of such processes was lacking; the explanation seemed speculative, and lacked a strong appeal. Its sufficiency is rejected by Wundt, for example, outright. But, stripped of its outworn modes of expression, stated in modern terminology, we have come to see that Spencer's account of the process as it takes place in the individual organism is not an hypothesis, but a fact. He is, in principle, describing the formation of a conditioned reflex. What he conceived as happening in his aquatic organism is exactly what does happen when a dog comes to react to a light or tone by the secretion of saliva, because he has been presented time after time with the tone or light stimulus simultaneously with the presentation of food which originally serves to excite the salivary secretion. It is again what happens when a human subject comes to react, as in Watson's experiments, to the tone of a bell by jerking his finger away from an electrode because auditory stimulus and electrical stimulus were given for a time in association with each other.

In the light of our present knowledge of such phenomena, there is no need of assuming that it is necessary, in order to show that modifications of behavior are transmitted, to suppose that innate responses as they appear today are the degenerate descendants of more complex and "voluntarily" acquired activities. The conditioned reflex affords a far more adequate and comprehensible method of explaining the origin of such reactions in the race.

There is in particular one class of reflexes which lend themselves admirably to interpretation as the results of just such a formation of conditioned reflexes in ancestral individuals and their transmission to following generations. The reflexes referred to are the glandular secretions which occur as elements of the responses to various emotional situations. We may therefore begin our discussion with a concrete illustration of one such secretion, and a consideration of the way in which it may be supposed to have arisen.

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<sup>3</sup> Spencer. *Principles of Psychology*. 3d ed., pp. 435-440.

In Cannon's remarkable discussion of the bodily changes in fear, pain, and rage, he has demonstrated that the secretion of adrenin under the influence of emotional states "plays an essential rôle in calling forth stored carbohydrates from the liver, thus flooding the blood with sugar; it helps in distributing the blood to the heart, lung, central nervous system and limbs, while taking it away from the inhibited organs of the abdomen; it quickly abolishes the effects of muscular fatigue; and it renders the blood more rapidly coagulable."<sup>4</sup> Each of these responses is, as he goes on to show, useful to *an animal undergoing severe muscular exertion and bodily injury*. The increased blood sugar increases muscular energy; the value of the shift of blood to the heart, lungs, central nervous system and limbs, the abolition of the effects of fatigue, is obvious, as is that of the increased rapidity of coagulation to the injured animal. The whole picture is thus that of an animal preparing himself for a great muscular excitation and possible injury which he is to be called upon to undergo.

But how may such a state of affairs have arisen? The clue seems to be furnished by Cannon himself a few pages further on. For it has been demonstrated by several observers that a moderate degree of asphyxia, such as that resulting from severe exertion, brings about the secretion of adrenin with all its attendant phenomena. In all this, says Cannon, we have a mechanism by which, when the actual stress comes, the changes already initiated by the anticipatory stimulus are continued and augmented. This is, to be sure, the state of affairs in the organism today, but is it not at least thinkable that the secretion of adrenin occurred originally in the race in response to the increase of carbon dioxide attending actual exertion? That the assumption is not incredible seems to follow from the further fact that Cannon is inclined to explain the phenomena of "second wind" by the arousal of the same mechanisms. "According to this explanation 'second wind' would consist in the establishment of the same group of bodily changes, leading to more efficient physical struggle, that are observed in pain and excitement." (p. 210.)

Now 'second wind' is a phenomenon that occurs whether previous emotional excitement has been present or not; the secretion takes place in response to the actual exertion, its stimulus being the presence of the physiological condition sensed as distress in breathing, etc. It is our contention that

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<sup>4</sup> Cannon, W. B. *Bodily Changes in Pain, Hunger, Fear and Rage*. pp. 184-185.

this represents the primitive state of affairs; that, in the race, the original stimulus to adrenin secretion was the exertion itself, not its "anticipation."

To start, then—since we must start somewhere—with an organism already possessing such a reflex mechanism as we have supposed. The mere presence of the object with which the organism had violently engaged in combat, or from which it had escaped in flight, would naturally come after a time to cause the responses which at first were induced by actual contact—conditioned reflexes, that is, would be formed, and the adrenin be secreted when the terrifying or anger-arousing object appeared. Such experiences are common enough under primitive conditions for the conditioned reflex thus established to become deeply ingrained in the nervous system of the animal, and are widespread enough to be common to the members of the race as a whole. The origin of the present mechanism for the secretion of adrenin was thus purely automatic, on the reflex level, and as a conditioned response to common and intense situations—the presence of fear and anger-provoking objects. Such a beginning as the result of individual experience offers a simple and clear explanation of its occurrence in existing forms.

The phenomenon with which we have been dealing does not stand in isolation. Crile holds that it is possible to stimulate the thyroid, adrenals and hypophysis *only* through the "distance ceptors"—that is, by what we may call "anticipatory" stimuli. "According to our observations, no amount of physical trauma inflicted upon animals will cause hyperthyroidism or increased adrenalin in the blood, while fear and rage do produce hyperthyroidism and increased adrenalin."<sup>5</sup> Crile, to be sure, makes too broad a generalization, as Cannon has conclusively shown that, in the case of the adrenals, stimulation of the sciatic nerve such as would, in the normal animal, be extremely painful, does cause adrenal secretion—the presumption is naturally that in the normal animal stimulation of the appropriate "contact ceptors" would produce the same response. (Op. cit. pp. 59-62.)

But it is none the less a significant fact that stimulation of the distance receptors seems to play a predominant rôle in exciting these glands of internal secretion. It is exactly the state of affairs that we should expect to find if such phenomena had, in the race, arisen as conditioned reflexes; as responses once given to contact, but now to the mere presence of significant objects.

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<sup>5</sup> Crile, G. W. *The Origin and Nature of the Emotions*. 1915, p. 133.

Crile himself does regard them as the results of ancestral life-experiences; his term is "phylogenetic associations;" but he nowhere puts himself on record as to the definite method by which, in the primitive individual, he supposes them to have arisen; whether as lapses from more complex forms of behavior, or by means of the formation of such conditioned reflexes as we have been supposing. He contents himself with such general statements as that "their origin is in the operation of the great laws of evolution." (p. 107.) His general positions, however, are such as to imply that in his opinion they did arise in the automatic fashion described.

But such glandular secretions are not the only phenomena of emotional response which may be explained as having arisen by the method which has been suggested. We may, with Crile, go further. His general thesis as to the significance of the emotional pattern as a whole is as follows. The presence of emotional responses means the integration of the body for the performance of the appropriate acts—the racially adequate responses of combat, etc.—but these, because of the influence of the civilized environment are not carried through. "When our progenitors came in contact with any exciting element in their environment, action ensued then and there. There was much action—little restraint or emotion. Civilized man is really in auto-captivity. He is subject to innumerable stimulations, but custom and convention frequently prevent physical action. When these stimulations are sufficiently strong but no action ensues, the reaction constitutes an emotion. A phylogenetic fight is anger; a phylogenetic flight is fear; a phylogenetic copulation is sexual love, and so one finds in this conception an underlying principle which may be the key to an understanding of the emotions and of certain diseases." (Op. cit., p. 76.) Stimulation of the "distance ceptors" by given objects arouses the responses originally made in the race when the "contact ceptors" were stimulated by the same objects. "Sight, sounds, and odors are symbols which awaken phylogenetic association. If a species has become adapted to make a specific response to a certain object, then that response will occur automatically in an individual of that species when he hears, sees, or smells that object." (p. 135.)

Our concern is merely with that phase of Crile's theory which ranges the motor phenomena of emotional expression with the glandular responses already discussed. These, too, may be conceived as responses originally given to actual and stressful contact, but now to the anticipatory situations which,



it may be assumed, were at first relatively indifferent to the organism. The responses of our skeletal muscles at the sight of a snake, then, are those once given by our ancestors to its attack, the muscular tensions of anger, like the adrenal responses, are the original responses to physical contact.

This general point of view is by no means new. It will be remembered that Darwin's explanation of many forms of emotional expression by the principle of "serviceable associated habits" is in principle the same: "Certain complex actions are of direct or indirect service under certain states of the mind, in order to relieve or gratify certain sensations, desires, etc., and whenever the same state of mind is induced, however feebly, there is a tendency through the force of habit and association for the same movements to be performed, though they may not be of the least use. Some actions ordinarily associated through habit with certain states of the mind may be partially repressed through the will, and in such cases the muscles which are least under the separate control of the will are the most liable still to act, causing movements which we recognize as expressive."<sup>6</sup> Others have made use of the same explanation; Stanley, for example, in his "Evolutionary Psychology of Feeling," regards fear as "anticipatory pain;" its origin was in the realization as a result of past individual experience that various situations meant the approach of pain. The same attitude is implied in much of Hall's work; and it is indeed impossible to hold that emotions are to be explained as the results of modifications of ancestral behavior without holding to the theory in some form.

But to make such general statements as that emotional responses have arisen as a result of "association" and "habit," leaves the question of the mechanisms involved still vague and unsatisfactory. Crile has worked out the idea of such "phylogenetic associations" more definitely than any one else. His discussions are free from many of the vague expressions which Darwin, in the light of the knowledge of his day, was forced to use. He has, moreover, increased the sweep of the theory by bringing under it such glandular phenomena as those mentioned above; responses which Darwin explained by the quite different principle of the "direct action of the nervous system." (Op. cit., p. 68.) And, as mentioned above, his whole attitude is such as to make it seem probable that his conception of the origin of the phenomena is that they arose in the same mechanical fashion that we have assumed in using the term "conditioned reflex."

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<sup>6</sup> The Expression of the Emotions in Man and Animals. p. 28.

It is just this conception of the origin of the phenomena on the reflex level which frees the theory from the vagueness with which it is usually stated.

Assuming, then, that such phenomena did first arise as conditioned reflexes, the physiology of their formation seems, in principle, clear. Suppose, for example, that the organism is engaged in combat. He is being stimulated not only by the teeth and claws of his adversary, but at the same time by his form, odor, and the sounds which he may emit. The stimuli from tooth and claw have the right of way; they are of the fundamental sort which, as Sherrington has shown, gain possession of the final common paths. Impulses from the receptors of eye, nose, and ear, will in such a case ally themselves with the more fundamental impulses, they will drain into the same final paths. Thus the connections from eye or nose stimulated by the enemy, to laboring muscle and secreting gland will become of lessened resistance, and after one or several experiences of like nature the stimulation of eye or nose will result in the muscular and glandular responses. We may go still further. A threatening growl, for example, though not heard during the combat itself, would, if a typical preliminary to combat, come to evoke the responses. For the mechanisms aroused by the growl would still to some extent be active in the immediately following combat, and would drain into the paths of the predominant mechanisms, with a consequent lowering of resistance as before. It is as simple to explain such phenomena as racially conditioned reflexes, as it would be absurd to suppose that adrenals and the rest somehow, at first under the influence of "the will" and later, under that of "habit," came to secrete in response to mental states called "fear" or "anger."

To show that it is thinkable that such responses may have arisen as results of the formation of conditioned reflexes in individuals is naturally not to convince the sceptic that they did actually so arise. But there is one fact about the emotional responses, muscular and glandular alike, which is worth noting in this connection. It is that, while such responses are eminently adaptive, they are adaptive, not so much in the situations in which they now occur, as in situations which, in the history of the race, typically followed. That some of these responses are not only, in the situations in which they occur, not serviceable, but that they are actually harmful unless those situations are followed by the racially appropriate acts, has been shown in some detail by Crile, in the work cited above.

It is easy to explain these facts on the basis of our proposed theory. But, those who deny the possibility of the inheritance of acquired characters would naturally retort, it is also possible to explain them without resorting to such hypotheses. For, once they appeared as variations, they would be useful to a degree in preparing the organism for the following exertion; and their harmful effects in man today are due to the changes in his life which civilization has wrought. More, the view is growing that all variations need not be useful in order to be preserved; such responses might be retained once they appeared as variations (mutations) if only they were not harmful enough to be a handicap to the animal, as obviously, under primitive conditions, they were not.

But if the responses did appear as variations, either continuous or discontinuous, it was naturally as variations from some not too different state of affairs already existing, and the argument lies near that this pre-existing state of affairs was that in which the responses were given to situations involving actual physical exertion. If this is the starting point, the question is, did the transfer of the responses to the anticipatory situations come about through variations or through the formation of conditioned reflexes? The more we realize the complexity of the emotional responses, the less credible does it seem that element after element, or the whole integration, should so have been transferred through variation. That one, or several responses might, is understandable; but that the whole picture of an organism under great bodily stress should have been projected, so to speak, by variation, on another and anticipatory type of situation, not once but many times, is hardly to be believed, especially when the simpler alternative is available.

Every element in the classic description of the fear responses which Darwin has given, spells in words of one syllable struggle, flight and the exhaustion which results. As he himself says: "Men, during numberless generations, have endeavored to escape from their enemies or danger by headlong flight, or by violently struggling with them; and such great exertions will have caused the heart to beat rapidly, the breathing to be hurried, the chest to heave, and the nostrils to be dilated. As these exertions have often been prolonged to the last extremity, the final results will have been either prostration, pallor, perspiration, trembling of all the muscles, or their complete relaxation and now, whenever the emotion of fear is strongly felt, though it may not lead to any exertion,

the same results tend to reappear, through the force of inheritance and association." (Op. cit., p. 307.) Is it not almost unthinkable that continuous variations or mutations should have built up such an integration, in a situation in which it is of little value and even at times of great harm to the organism—an integration which moreover copies so perfectly the picture of responses to a second sort of situation (flight and exhaustion), which in the life histories of "numberless generations" closely followed on the sort of stimulation to which the fear responses are now given? Is it conceivable that such copies should be evolved by variations and that not in one emotion, but in many, and down to minute detail in case after case? To affirm this savors of a mysticism that is almost Bergsonian. Truly the facts of emotional response offer but a slippery footing to advocates of the all-sufficiency of variation. Darwin himself seems to have seen this clearly; it is not by accident that in the "Expression of the Emotions," explanations by variation have retreated to the background.<sup>7</sup>

We must not forget, in considering the possibility of the inheritance of acquired modifications of behavior, that in one case such a transmission seems to have been shown unquestionably. This is the case reported by Kammerer, dealing with his work with the obstetrical toad.<sup>8</sup>

Kammerer compelled the animals, whose eggs are normally laid on land and taken up and carried about for a time by the male, to breed in the water, which normally they rarely

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<sup>7</sup> The writer's picture of the transmission of such responses would be this: The responses made by the animal under conditions of stress depend obviously on the nature of his "action system" (including glandular reactions). The conditioned reflex, when formed in the individual, arouses the whole pattern of responses which the animal originally gave to the stressful situation. The resulting modification of the germ plasm is of such a nature that, though possibly only one substance may cause it, the whole pattern of responses will be reproduced in following generations. (One may remember here the phenomena of concomitant variations). The modification may at first be slight, the tendency to give the responses in anticipatory situations by the offspring, feeble. The life experiences of these organisms would strengthen the tendency, and after several or many generations it would gain the strength which it now has. As, in the course of evolution, the animal's action system changes, his responses to stressful situations change, and new elements are added by his experiences to his emotional responses; the pattern thus becomes different in the individual, the modification of the germ plasm is different, and the resultant behavior in the offspring is different.

<sup>8</sup> Kammerer, P. *Vererbung Erzwungener Fortpflanzungsanpassungen*.—III. Die Nachkommen der nicht Brutpflegenden *Alytes* obstetricans. Arch. f. Entwickl., 1909, 28.

visit. After several seasons of compulsion, the animals came to breed in the water, even when the compelling stimuli were withdrawn. The broods reared from the eggs of this generation showed (after the first), increasing modifications of their breeding instincts in the direction of the modifications acquired by their parents. The later broods would breed the first season in the water, the second on land without the characteristic taking up of the eggs by the male, and only in the third breeding season did they revert to the normal ancestral behavior. In this case, a continued experience of one generation was sufficient to modify the behavior of a second generation. The acquisition of the modified form of behavior in the first generation has about it nothing "voluntary" or "deliberate," nothing that suggests analysis of the situation. Kammerer's method of causing the animal to breed in water was by the use of high temperatures at the breeding season. To such stimulation the animal responded as his innate mechanisms impelled—he sought the water reflexly. The situation "a high temperature" and the situation "a certain physiological state characteristic of the breeding season" occurred several times together, and were invariably followed by the response "going to the water." It naturally followed that the physiological state characterizing the breeding season came to cause, when present alone, the water-seeking response. The mechanism is again that of the conditioned reflex.

It seems significant that this modification, so promptly transmitted, was a modification in an element of a behavior-complex (breeding behavior) that is obviously characterized by deep and widespread bodily reverberations. When we come to know even as much of the bodily changes which characterize the operation of the instinctive breeding-mechanisms as we do of those characteristic of fear and rage, we will in all likelihood see that no organ or tissue of the body is exempt. How widespread are even the superficially observable responses in such a case is well shown by Craig, who, in speaking of the behavior of the female ring-dove who has thrown herself into the mating and laying attitude, says "When she does so, her whole organism is affected. Her position in standing and her carriage in walking are greatly altered—her whole bearing shows intense emotion, not violent, but deep."<sup>9</sup>

It has been argued above that it is in cases characterized by just such a sort of behavior that the evidence for the trans-

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<sup>9</sup> Craig, Wallace. The Stimulation and the Inhibition of Ovulation in Birds and Mammals. *Jour. of Animal Behavior*, 1913, 3, 215.

mission of acquired modifications is strong. The responses now emotional were originally given, we have assumed, to situations which, like that with which Kammerer was dealing, involved the widest sort of bodily resonances. The organism was, *as a whole*, integrated for the combat he was undergoing, the injury he was receiving, the flight he was undertaking.

In the breeding responses, again, the animal is integrated for one end alone. May we not, then, venture to assume that the cases in which it is most likely that acquired modifications of behavior have been inherited are those *in which the situations to which the responses were originally given were attended by a wide degree of integration of the organism as a whole in the service of some fundamental task*. That such situations would in the individual be highly favorable for the formation of deeply ingrained conditioned reflexes is obvious. And that such conditioned reflexes themselves involving the same thorough integration would be more likely than those of a milder nature to modify the germ-plasm seems evident.

We have so far attempted to show that, in cases of emotional responses, an origin as conditioned reflexes offers a simple explanation of the phenomena as they actually appear, while their origin as slight variations or as mutations is difficult to explain, since they do copy so closely life experiences of the animal in typically associated situations. Kammerer's case of the actual transmission of an acquired modification of behavior shows the mechanism of the conditioned reflex in the individual, in a situation involving integration of the organism for a fundamental purpose, and we have been led to the statement that conditioned reflexes formed under circumstances which involve such integration—as in the conditions of stress from which emotional responses derive, or those involving the operation of fundamental instincts—would be in a favorable position to bring about modifications of the germ-plasm.

But such a statement remains unconvincing unless it is possible to show that a means exists by which such conditioned reflexes may modify the germ-plasm, while others of different type may not. There is, as a matter of fact, a recent theory of the mechanisms involved in the transmission of acquired characters which lends support to our assumption. Cunningham has contended that the germ-plasm may be modified through the action of hormones secreted by various bodily structures and carried by the circulation to their destination. There is evidence that the germ-cells affect the soma in such a way, and it is only natural to assume that the

process may be reversed.<sup>10</sup> Now conditioned reflexes which have arisen in the race from integrations of the fundamental nature we have been describing do as a matter of fact involve as a part of their nature the activity of those cells which produce such internal secretions. Hence, once acquired by the individual, they are in a strategic position so far as modifications of the germ-plasm are concerned. They are characterized by the production of internal secretions; conditioned reflexes of a less fundamental sort acquired by the individual are less likely to be so accompanied.<sup>11</sup>

The theory proposed above that inheritance of acquired modifications of behavior is most likely to occur in the case of those experiences which the individual meets by an intense and thorough integration may also serve to show why certain types of racial experience are not inherited but must be acquired afresh by each generation. It weakens, for example, the force of evidence of the sort cited in the following quotation.

"It is remarkable that certain evidence from human psychology has failed to receive attention in all these long debates. Human life offers a favored case for transmission of an acquired trait where transmission has clearly failed. The congenitally blind from eye defects do not have visual images of the sun, stars, or any other of the permanent objects of the natural world, yet their ancestors for at least hundreds of generations, save in the case of those lacking in visual images, had such images again and again. If the hourly experiences of hundreds of ancestral generations do not become a part of inborn equipment, we could hardly expect anything to do so."<sup>12</sup>

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<sup>10</sup> Cunningham, J. T. *The Heredity of Secondary Sexual Characters in Relation to Hormones*. Arch. f. Entw. 1908, 26.

<sup>11</sup> It is necessary, in making such an assumption, to remember that Cannon has argued that the glandular responses, and the activities of the autonomic system in general, are too similar in the various emotions to serve as a basis for the actual differentiation of these in the individual. Their distinguishing features, he holds, are furnished by the central nervous system. (Cannon, W. B. *The Interrelations of Emotions as Suggested by Recent Physiological Researches*. Am. Jour. Psy., 1914, 25, pp. 256-282.) Angell has replied that, while single elements may be much the same, the patterns may be very different. (Angell, J. R. *A Reconsideration of James's Theory of Emotion in the Light of Recent Criticisms*. Psy. Rev., 1916, 23, pp. 251-261.) This may of course be true of the glandular as well as of the motor phenomena involved. There is also the possibility of slight chemical differences in the secretions in the various responses, and of the presence of other secretions as yet unknown. We must remember that systematic work in this field is in its infancy.

<sup>12</sup> Thorndike. *The Original Nature of Man*. p. 234.

Thorndike's case, on our hypothesis, is not crucial at all. For the permanent phenomena of the world are not faced by organisms with a high degree of integration. Nor do the responses which, in the course of individual experiences, are built up as images of those objects, involve the taking of such definite and integrated bodily attitudes. Even if it became necessary to adopt the extreme position of Watson, that visual images are in reality nothing but the direct sensory results of slight motor adjustments, it is evident that the motor phenomena involved are not of such a nature as by our hypothesis we would expect to be able to bring about modifications in the germ-plasm. On the other hand, man *does* inherit responses to temporary and violent disturbances in natural phenomena, in the various sorts of fear responses, for example. In Hall's returns, fears of this sort rank high<sup>13</sup> and it is easy to see how the organism at first reacting intensely to the effects of such disturbances on itself and its fellows, could come by the formation of racially conditioned reflexes to react as it now does to their mere appearance. We do not, to be sure, react by getting images of their effects, but in the more natural way of reproducing the confused mental states and the bodily attitudes originally produced by those effects. There is no disposition to discuss here the question whether man ever does inherit responses to ideas or by ideas. A consideration of the confusing evidence may be reserved for another paper. But it is evident enough that ideas of permanent natural objects lack the essential physical bases which would make their inheritance likely. Our contentions may be summarized as follows:

1. The supposition that man's innate responses have arisen as the results of acts performed at first, in the race, in a deliberate, or voluntary fashion, with analysis of the attendant situations, with "conscious intent," and subsequently mechanized by the individual and so transmitted, is unlikely, from what is known of animal behavior.

2. There is however, another method by which modifications of behavior do take place in organisms which can easily account for the origin in ancestral organisms of many forms of behavior which we are supposing to have been transmitted. This method is that of the formation of conditioned reflexes.

3. Glandular responses such as those given in strongly emotional situations become easily comprehensible if they are viewed as conditioned reflexes which, once set up in ancestral organisms, were transmitted.

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<sup>13</sup> Hall, G. S. A Study of Fears. Am. Jour. Psy., 1897, 8, pp. 147-249.



4. Not only such glandular reactions, but the whole pattern of emotional response, is easily understandable on such a hypothesis. It is almost unthinkable as a copy of the responses to another type of situations (actual flight, combat, etc.), arising from variations.

5. Kammerer has shown that modifications in the breeding behavior of one species of toad—behavior involving deep and widespread bodily resonances—are transmitted.

6. It seems possible, then, to argue that modifications in forms of behavior attended by intense and thorough integration of the organism are likely to be inherited.

7. Such a theory receives at least partial support from the "hormone theory" brought forward by Cunningham.

8. The theory propounded in (6) also serves to explain why certain sorts of ancestral experiences are not inherited.

It remains to note that this paper is not an attempt to explain all sorts of innate behavior as having arisen by the method suggested. There is no reason to deny the origin of perhaps much of man's original behavior in variations, whether of the continuous sort supposed by Darwin, or the discontinuous mutations which are now so much stressed. Both variations and the transmission of acquired modifications seem to have been at work; one theory does not exclude, but supplements, the other.

And, finally, the view of the "original nature of man" to which such a theory leads makes it far richer than advocates of the all-sufficiency of variation have supposed. But the discussion of such implications of the theory may be reserved for another occasion.